"Effects of Prolonged Heating on the Magnetic Properties of Iron. (Second Paper.)" By S. R. Roget, B.A. Communicated by Professor Ewing, F.R.S. Received October 26—Read December 8, 1898.

In a paper by the author, read before the Royal Society on May 12, 1898,* the results of some experiments were given showing the change in the value of the hysteresis of soft iron transformer plate when subjected to continued baking at temperatures not exceeding 200° C. The experiments there described have since been extended to higher temperatures, and the results for heating at temperatures up to 700° C. are given below.

The same specimens were used as in the former experiments, consisting of soft Swedish iron transformer plate which had been re-annealed. The baking at these high temperatures was carried on in a specially constructed electric oven heated by coils of platinum wire wound on a mica frame, inside a metal vessel completely surrounded by a lagging of silicate cotton except for a mica tube through which the specimens and thermometer were introduced. By this means, any desired temperature could be maintained up to a bright red heat, so that the apparatus could be also used as an annealing furnace. As the specimen and thermometer were situated within the heating coil they could be very rapidly brought up to the desired temperature, which was read direct on a Callendar-Griffiths platinum pyrometer. Regulation was effected by alterations in the grouping of the coils as well as by outside resistances. The measurements of hysteresis were made as before with Professor Ewing's hysteresis tester, the specimens being removed periodically from the oven and tested at atmospheric temperature.

A number of short runs at various high temperatures were taken. The results given in Table I and fig. 1 represent the means of several independent observations at each temperature.

The absolute values of the hysteresis are given in ergs per cubic centimetre per cycle (for $B = 4000$), together with the rise expressed as a percentage of the initial hysteresis to the nearest 1 per cent. The general features of the action are similar to those noticed before at more moderate temperatures. They should be compared with fig. 2 of the former paper. The initial rise of hysteresis is more rapid the higher the temperature, but the subsequent fall takes place sooner, and the final state is one of lower hysteresis the higher the temperature, until at about 700° C., a temperature just short of that required for complete annealing, the hysteresis falls again to quite its original value

* 'Roy. Soc. Proc.,' vol. 63, pp. 258—267.

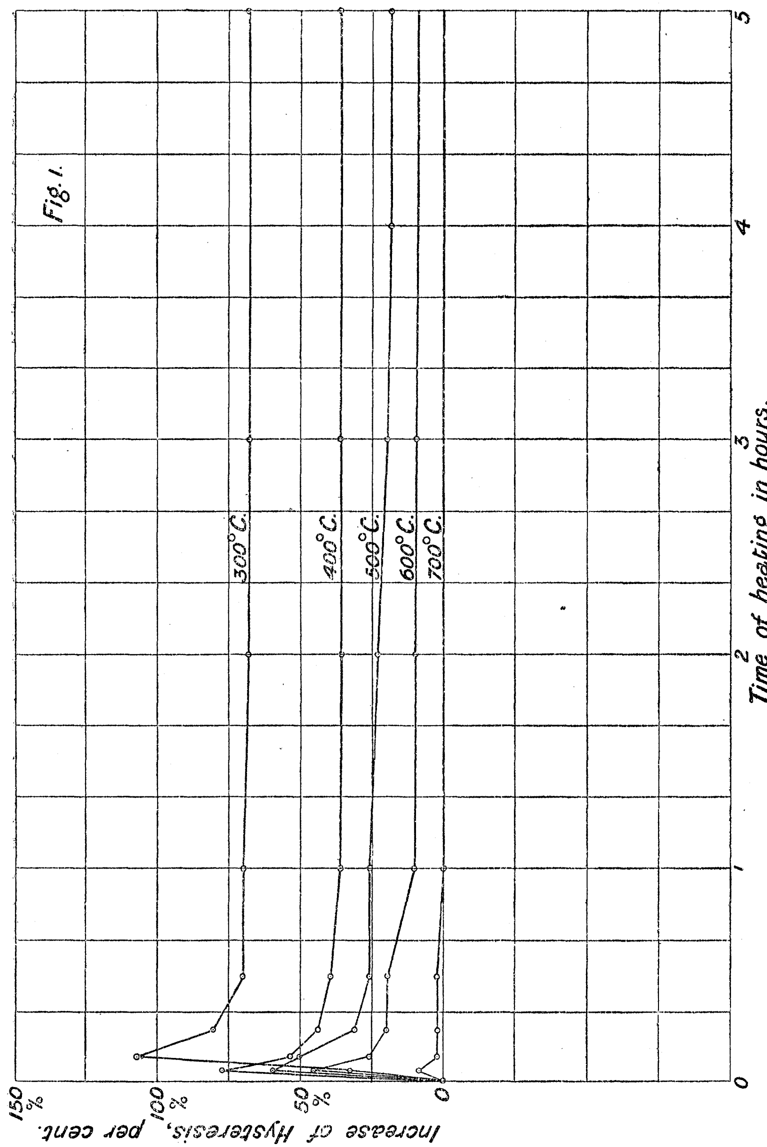


Fig. 1.

after a very short time. At temperatures above this, no trace of any rise has been observed.

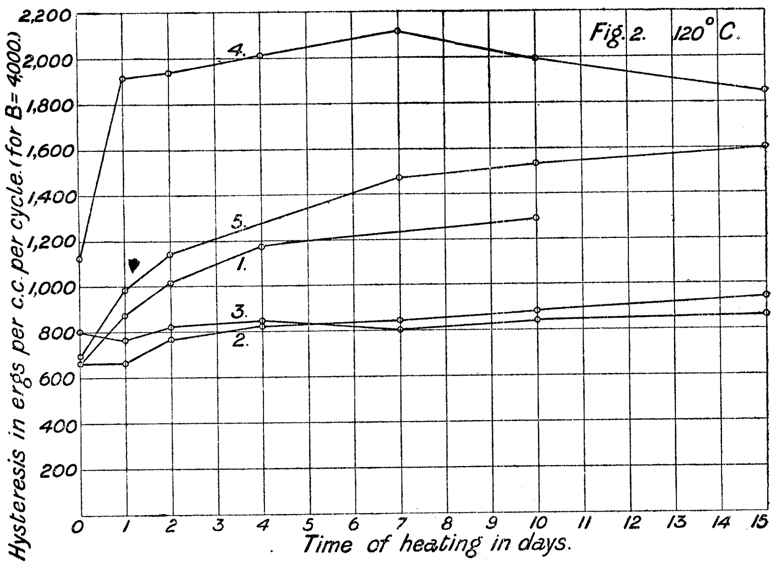
The question at once suggested itself whether iron which had been heated at a constant temperature with the effect of causing its hysteresis to pass a maximum and to become reduced, would have its hysteresis again increased by exposure to more moderate temperatures,

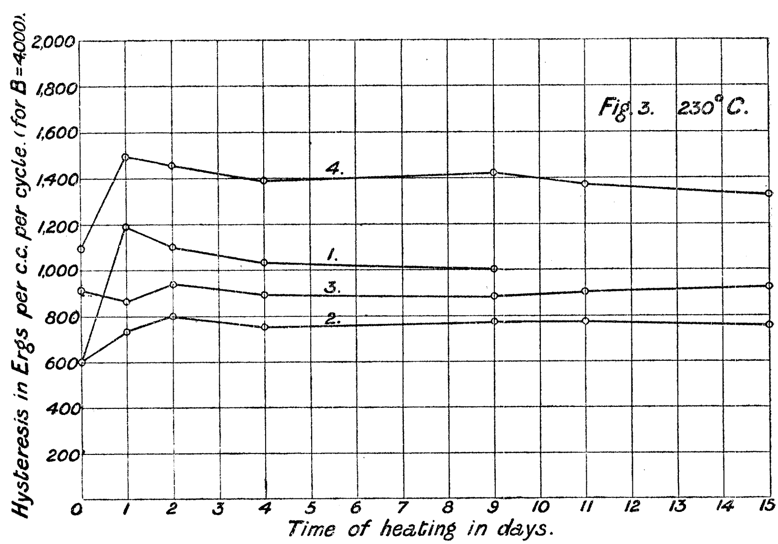
or would show some degree of immunity to temperature effects. It was found that the susceptibility to change at moderate temperatures was not by any means entirely removed by prolonged heating at high temperatures. The subsequent action of low temperatures was, however, slower than in freshly annealed iron, especially after the high temperature had been applied for a considerable time, also it appeared that temperatures at 500° or 600° C. produced less effect on the susceptibility to subsequent change at lower temperatures than was produced by more moderate degrees of preliminary heating. A complete series of experiments on this point, however, has not yet been made, only a few samples having been re-heated in this way, but the results obtained with these were consistent, and pointed to the above conclusions.

The latter part of the action at the higher temperatures resembles an incomplete annealing, as there appears to be little difference between the state after the iron has been heated for a few hours at a temperature just short of the "critical" temperature at which ferromagnetic quality disappears, and that of the same material which has been heated above this temperature so as to become completely annealed.

The above experiments, and those in my previous paper, refer to one particular brand of iron, all the specimens having come from the same sheet. A few examples, showing how widely different is the behaviour of different brands of steel and iron, are given in figs. 2 and 3. The data for these diagrams are to be found in Tables II and III, where the absolute values of the hysteresis in ergs per cubic centimetres per cycle are given together with the rise expressed as a percentage of the initial hysteresis.

Figs. 2 and 3 relate to various samples of commercial iron and steel, some of which were supplied by makers in this country and some from America. Fig. 2 shows the effects of heating at 120° C., and fig. 3 shows the effects of heating specimens of the same iron at 230° C. The curves, numbered alike in both figures, refer to the same material. All these samples were initially in the annealed state. No. 1 is a piece of the iron used in the previous experiments, and is given here for the sake of comparison. No. 2 is a sample of special transformer steel of equally low initial hysteresis. The action of heat on it is similar in general characteristics to the action of No. 1, but much less in degree. No. 3 is practically "non-ageing," even in the annealed state, and although not of such low initial hysteresis as some of the other specimens, would be the most suitable for transformers on account of its immunity from change by prolonged heating. No. 4 is a sample of sheet-iron not specially made for transformers; it is of poor magnetic quality, but is interesting as showing, at 120° C., effects which require a higher temperature in the other brands of iron; the initial rise is very rapid, and the subsequent fall of hysteresis is clearly shown, even at





this temperature. No. 5 shows greater rise than No. 1 at 120° C. in the annealed state, although this identical sample appeared to be practically unaffected by heating for a fortnight in the state in which it was supplied, but was then of somewhat higher initial hysteresis. It is interesting to notice that this iron if annealed before use in a transformer would ultimately, through low temperature heating, show much

more hysteresis than if left in the state in which it was submitted by the manufacturer.

The author has no information as to the treatment by which this remarkable degree of "non-ageing" quality had been produced. The general characteristics of the action at 230° C. on the different samples (see fig. 3) are much the same, differing only in degree. No. 3 is, again, little changed by prolonged heating.

It seems from these and other tests, that brands of transformer steel, which are practically "non-ageing," are obtainable commercially, but they are not (at least in these examples) of such low initial hysteresis as the "Swedish iron," which was formerly considered the best material for transformers. The effects of annealing vary much in different samples. All the samples tested after annealing have been found to be more liable to change in that state than in the state in which they were supplied by the makers. The method of annealing and rate of cooling may have much to do with the "non-ageing" quality of the material. Incidentally the experiments have given some evidence that samples of iron may undergo a slight change in hysteresis, even if kept at atmospheric temperature for three or four years.

It may be convenient to briefly summarise the chief effects of prolonged heating on the magnetic properties of iron which have been observed in these and the previous experiments.

1. Material in the annealed state is more liable to change than in a harder state.

2. All the changes produced by prolonged heating are completely removed by re-annealing.

3. The heating need not be continuous; the same cumulative effect is produced by a number of short periods at a given temperature as by a continuous heating at the same temperature.

4. The effect may be regarded as being due to two actions superposed, one tending to increase the hysteresis, this action being the more prominent at lower temperatures; the other analogous to an incomplete annealing, tending to decrease the hysteresis, this action predominating at higher temperatures.

5. The liability of the material to increase in hysteresis at moderate temperatures is not removed by prolonged heating at high temperatures.

6. The change is confined to the lower part of the B.-H. curve, the saturation value of the magnetisation being substantially unaltered.

7. The effect is produced equally, whether the iron is or is not exposed to the air during heating.

In conclusion the author wishes to express his thanks to Professor Ewing, for placing at his disposal the facilities which have enabled these experiments to be carried out, and for much other kind help.

Table I.—Change of Hysteresis by Prolonged Heating at High Temperatures.

Temp.	300° C.		400° C.		500° C.		600° C.		700° C.	
	Hysteresis.		Hysteresis.		Hysteresis.		Hysteresis.		Hysteresis.	
Time of heating.	Abs.	Incr. per cent.	Abs.	Incr. per cent.	Abs.	Incr. per cent.	Abs.	Incr. per cent.	Abs.	Incr. per cent.
0	560	0	590	0	620	0	590	0	640	0
3 m.	750	34	1040	77	990	59	860	46	690	8
7 ,,	1160	107	900	53	940	52	750	27	650	1·5
15 ,,	1010	80	850	44	810	31	710	20	650	1·5
30 ,,	950	70	820	39	780	26	700	19	650	1·5
1 hr.	950	70	800	36	780	26	640	9	640	0
2 ,,	940	68	800	36	760	23	640	9	640	0
3 ,,	940	68	800	36	740	19	640	9		
5 ,,	940	68	800	36	730	18				
1 day	860	54	790	34	730	18				

Table II.—Various Brands of Iron and Steel heated at 120° C.

No. of specimen.	1.		2.		3.		4.		5.	
	Hysteresis.		Hysteresis.		Hysteresis.		Hysteresis.		Hysteresis.	
Time of heating, days.	Abs.	Incr. per cent.	Abs.	Incr. per cent.	Abs.	Incr. per cent.	Abs.	Incr. per cent.	Abs.	Incr. per cent.
0	660	0	660	0	800	0	1120	0	690	0
1	870	32	660	0	760	−5	1910	71	980	42
2	1010	53	760	15	810	1	1930	72	1140	51
4	1170	77	820	24	840	5	2010	80	..	..
7	..	..	840	27	800	0	2110	89	1470	113
10	1290	96	880	33	820	2	1990	78	1530	122
15	..	..	940	42	830	4	1840	64	1600	132

Table III.—Various Brands of Iron and Steel heated at 230° C.

No. of specimen ...	1.		2.		3.		4.	
	Hysteresis.		Hysteresis.		Hysteresis.		Hysteresis.	
Time of heating, days.	Abs.	Incr. per cent.	Abs.	Incr. per cent.	Abs.	Incr. per cent.	Abs.	Incr. per cent.
0	600	0	600	0	910	0	1090	0
1	1190	98	730	22	860	−8	1490	37
2	1100	77	800	33	940	3	1450	33
4	1030	72	750	25	890	2	1390	27
9	1000	67	770	28	880	3	1420	28
11	..	..	770	28	900	1	1370	24
15	..	..	750	25	910	0	1320	19

"On the Topographical Anatomy of the Abdominal Viscera, especially the Gastro-Intestinal Canal in Man." By CHRISTOPHER ADDISON, M.D., B.S. (Lond.), F.R.C.S., Professor of Anatomy, University College, Sheffield. Communicated by Professor ALEXANDER MACALISTER, F.R.S. Received October 15—Read December 8, 1898.

(Abstract.)

General Purpose.

This paper embodies the results of an enquiry into the topographical anatomy of the abdominal viscera in man. The work falls into two main parts. First, that dealing with the relations of the viscera to the surface of the body; and, second, that dealing with the relations of the viscera to one another.

With regard to the first part: It is to be remarked that the methods of mapping out the abdomen at present in general use are open to certain objections; for the reasons that the lines used to divide the abdomen transversely are drawn at variable distances from one another, the variation not being determined by the dimensions of the body; that the points between which the upper transverse abdominal line is drawn are very variable in their level, so that in some cases the transverse lines come very near together leaving a large part of the abdomen above them not mapped out; in other cases the lines may be far apart; and, moreover, the points between which the upper transverse line is to be drawn are not always easily determined, and it happens